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THE ALFALFA CATERPILLAR.

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INTRODUCTION.

The alfalfa butterfly, *Eurymus eurytheme* Boisd. (fig. 1), is one of the most beautiful and interesting of the group of butterflies known as "the yellows"; beautiful because of its golden and orange colors which contrast so conspicuously with the bright green of alfalfa fields, and interesting because of the wide individual variation, extending from the white or albino forms to those that are deep orange. To the alfalfa grower in the Southwest, however, its chief interest lies in the great destructiveness of the larvæ (fig. 2.) One seeing the yellow butterflies darting here and there over a green alfalfa field would hardly suspect that a few weeks hence they would cause the same field to appear as brown, dead stubble. Yet this is what happens nearly every year to a greater or less degree in the Imperial Valley of California and in the Salt River Valley of Arizona.

FIG. 1.—The alfalfa caterpillar (*Eurymus eurytheme*); Female in the adult, or butterfly stage. One-half enlarged. (Author's illustration.)

It was not until 1910 that this butterfly was known to entomologists as a serious pest. Previous to that time reports received from

NOTE.—This bulletin is especially applicable to the Southwest, where the alfalfa caterpillar occurs in destructive numbers in irrigated alfalfa fields.

the Southwest, placing on this species the blame for injury to alfalfa, were doubted. In the spring of that year, however, the writer was detailed to investigate these reports in the Imperial Valley and discover whether the butterflies bore any relation to the destruction of alfalfa by a "green worm." His observations showed that the accusations were well founded, for in July, 1910, the butterflies were seen to lay the eggs that hatched into the green larvæ which ate up the alfalfa crop, causing a loss of thousands of dollars.

At the end of the first year's investigation, experiments and observations had been completed which were thought to be of immediate benefit to the ranchers in controlling the pest, and a preliminary report was made and published as Circular 133 of the Bureau of Entomology. During the three years subsequent to this preliminary

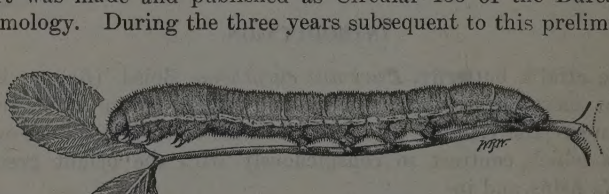

FIG. 2.—The alfalfa caterpillar: Full-grown larva. Enlarged about three diameters. (Original.)

investigation the writer and others have made a more exhaustive study of the species, its habits, and natural or artificial methods of control, and the object of this bulletin is to record these observations as they have been interpreted.

GENERAL DISTRIBUTION.

According to Scudder[1] this insect is well distributed over the United States, but is found in its greatest numbers in the Mississippi Valley (see map, fig. 3) and to the westward. In only a few cases does it appear east of the Allegheny Mountains, but its range extends northward into Canada, even as far as Hudson Bay. In 1911 Mr. R. A. Vickery made observations on the species at Brownsville, Tex., thereby considerably extending the southern range from that included in Scudder's map. In past years the species has been especially abundant throughout the alfalfa-growing sections where irrigation is extensively developed.

[1] Scudder, S. H. The Butterflies of the Eastern United States and Canada, v. 2, Cambridge, 1889, pp. 1131–1132.

ECONOMIC HISTORY OUTSIDE THE BORDERS OF ARIZONA AND CALIFORNIA.

In regions outside of Arizona and California this species has at various times been suspected, both by agents of the Bureau of Entomology and others, of doing more or less injury to alfalfa. In 1906 a correspondent of the Department of Agriculture reported the caterpillars as infesting lucerne fields in Brigham County, Wyo. In the same year another correspondent, writing from Dell, Oreg., reported the butterflies in "countless thousands playing on the alfalfa blossoms."

In 1909 Mr. C. N. Ainslie found eggs and larvæ on alfalfa at Springer, N. Mex., but not in sufficient numbers to be doing any apparent damage. In July, 1913, on nearly the same ground, the writer found larvæ quite abundant. It is apparent that the reason Mr. Ainslie did not find them in numbers was the lateness of the season. In the same year, 1909, Mr. E. O. G. Kelly, at Wellington, Kans., reported the larvæ as rather numerous on alfalfa plants and feeding freely; and the following year, at the same place, Messrs. T. H. Parks and H. T. Osborn observed the larvæ feeding upon alfalfa, and reared parasites therefrom.

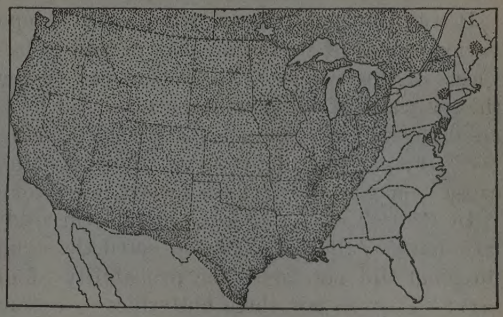

FIG. 3.—Map showing distribution of the alfalfa caterpillar. (Original.)

In 1910 Mr. R. A. Vickery, at Brownsville, Tex., reported the species as being abundant in the alfalfa fields as late as November. He states: "These larvæ are the most numerous and injurious of the several species of caterpillars that are injuring alfalfa now."

In the summer of 1911 the species was found in a number of localities, and reported by different members of the Bureau of Entomology as injuring alfalfa at the following places: Cokeville, Wyo., Idaho Falls and Blackfoot, Idaho (T. H. Parks); Ely, Nev. (C. N. Ainslie). In July, 1911, Prof. S. B. Doten, of the Nevada Agricultural College, received from The H. F. Dangberg Land & Live Stock Co., Minden, Nev., a letter reporting damage from this worm, an extract of which follows: "We are this day mailing you under separate cover a species of worm which at the present time is doing a great deal of damage in our alfalfa fields. They seem to congre-

gate on different parts of the field, and wherever they are the crops are totally destroyed." The same month Mr. Frank C. Jones, of Gardnersville, Nev., reported: "The caterpillar of the yellow butterfly is seriously damaging the alfalfa fields of Carson Valley. It seems to develop most abundantly about the time of the first cutting and feeds on the young shoots, retarding the growth perhaps two weeks."

During the season of 1913 the species was reported by Mr. E. H. Gibson as doing slight damage at Jackson and Nashville, Tenn., and at Greenwood, Miss. Here the butterflies were abroad from early April until late November and, while everywhere present, never seemed to do a great amount of damage. Mr. W. H. Larrimer, also working at Nashville, reported larvæ in considerable numbers.

ECONOMIC HISTORY IN CALIFORNIA AND ARIZONA.

It was Henry Edwards[1] who, in 1877, reported the occurrence at various times of what since has proved to be one of the many color forms of this species. No account can be found in which he treats the species as of economic importance, but he says: "This * * * is an abundant insect in clover and alfalfa fields from July to September," thus intimating that its numbers might be great enough to cause damage. Most of his records were for California.

In 1899 Prof. T. D. A. Cockerell,[2] in studying the insects of the Salt River Valley of Arizona, noted the abundance of these butterflies, but did not stress the probability of damage to alfalfa. He says: "I never saw these butterflies so extraordinarily abundant as they were last October at Phoenix. * * * These caterpillars being very numerous must eat a great many leaves and so reduce the crop, but it is probable that their ravages would not be very noticeable under favorable conditions of moisture and temperature. At all events, it is not practicable to take any measures against them." We have here the first record of the insect as actually destructive to alfalfa.

It would seem that after this, as irrigation in the warm valleys of southern Arizona and southern California began to be more highly developed and alfalfa became a more important crop, the damage became more noticeable each year. In 1907 Mr. Geo. G. Carr, writing to the Department of Agriculture from Hanford, Cal., reports considerable damage to alfalfa. An extract from his letter follows:

[1] Edwards, Henry. Pacific Coast Lepidoptera, No. 24. Notes on the genus Colias, with descriptions of some apparently new forms. *In* Proc. Cal. Acad. Sci., v. 7, p. 4, Feb. 5, 1877.

[2] Cockerell, T. D. A. Some insect pests of Salt River Valley and the remedies for them: Ariz. Expt. Sta. Bul. 32, p. 286–288, Dec., 1899.

FIG. 1.—ALFALFA PLANTS STRIPPED OF LEAVES BY ALFALFA CATERPILLARS. (ORIGINAL.)

FIG. 2.—HERDING TURKEYS AS A METHOD OF REDUCING THE NUMBERS OF DESTRUCTIVE INSECTS. (ORIGINAL.)

FIG. 3.—FIELD SHOWING IMPROPER CUTTING. THE ALFALFA CATERPILLAR THRIVES IN THE LONG STUBBLE. (ORIGINAL.)

As to the "cutworms," they result from the yellow butterfly, which is often noticed in the alfalfa fields in this valley. The butterfly lays an egg which hatches into the so-called "cutworm" [fig. 2]; the latter goes into the chrysalis state [fig. 6], which eventually results in another butterfly. Seemingly there are several crops of worms which hatch in one season. Whereas we have noticed these worms and butterflies in moderate numbers for years, yet never before have they attained the present great numbers.

In the fall of the year 1909, after a severe outbreak in the Imperial Valley of California during the summer, Mr. J. A. Walton, the owner of a large ranch in that valley, appealed to the Secretary of Agriculture for methods of handling the pest. Mr. W. E. Packard, of the California Experiment Station, reports that the worms are often quite numerous during certain years and cause more or less damage in the Sacramento Valley, and in the irrigated alfalfa regions of south-central California. Several fields that came under the writer's observation in 1910 made an entire failure of the third crop, while many others suffered a 40 to 60 per cent loss in a single hay crop, so that the damage for the year could be conservatively estimated at more than $500,000. (See Pl. I, fig. 1.) During that year (1910) there was also considerable damage in the Salt River Valley of Arizona, but compared with the damage in the Imperial Valley it was slight. In fact, as is explained in later paragraphs, injury was rarely as severe in any other locality as in the Imperial Valley.

During 1911 the bureau was unable to make any studies in the Imperial Valley, but Mr. Packard, who was continually on the ground, told the writer in the fall of that year that little damage was accomplished, the larvæ never being present in great numbers. As noted in a separate paragraph, the destruction of the larvæ in wholesale numbers the summer before by an apparently contagious disease had so checked the species that it was unable to make any headway during that season, and, in fact, as will be seen later, it required two years to readjust itself to conditions.

Throughout the season of 1911, during the writer's absence, Mr. E. G. Smyth, in the Salt River Valley, noted that while there was some damage the species was not numerous enough at any time to necessitate protective measures against it.

In 1912 the writer was again located in the Salt River Valley, and that year, although considerable damage was done by the alfalfa caterpillar, the work of the disease just referred to and of parasites was able to keep the species pretty well within bounds, so that only an occasional field was seriously damaged. The following quotations are from the writer's own field notes:

July 10, 1912: Butterflies are very numerous at this time and in many fields are actively depositing eggs.

July 22: Butterflies are very numerous now, filling the air everywhere. They are even flying around over town in great numbers. Over an alfalfa field north of town they are simply swarming. Millions of them present over the blooming alfalfa where they are feeding. A field just across the road that had been recently cut had the alfalfa covered with eggs. These are adults of the third generation.

Aug. 1: Eurymus larvæ are very abundant now and in a few fields beginning to do considerable damage. On Mr. Aepli's farm 1 mile south of town the caterpillars were exceptionally numerous and damage considerable. However, Mr. Aepli cut his crop of hay and stopped their work by disking. There were 257 larvæ to the square yard counted in this field.

In the Imperial Valley in 1912 the fourth hay crop, about August 1, was nearly one-third lessened by the feeding of the caterpillars, but the damage, although heavier than in the previous year, in no way compared with that of 1910 or 1913. During July, 1913, Mr. Walter Packard wrote to the author, telling him of a great outbreak around El Centro and suggesting that something should be done at once, as practically all of the third crop had been destroyed. As the writer was in northern New Mexico, engaged on other work, Mr. R. N. Wilson was instructed to proceed to Imperial Valley and investigate the outbreak. Upon his arrival there he found the damage to be very heavy, but over for the year, as the species had again been checked by the disease. The conditions are best told in his original field notes, which follow:

El Centro, July 14, 1913: Some of the fields [alfalfa] were visited this morning, and it immediately became obvious that if the bacterial disease is as prevalent in all of the fields in the valley as in those visited this morning it is now too late to try cultural methods, brush dragging, disking, etc., as most of the larvæ are dead. I am told that last week was very warm during the entire week and that the humidity was high. This was probably just the right condition for the disease to spread, and hence the cause of the death of millions of the larvæ. Many of the fields about El Centro have been cut recently and so show nothing now as to *Eurymus* conditions; many are also being pastured, and in these the caterpillar attack is slight. In some fields which have not been either pastured or cut the damage is considerable, but very few healthy larvæ or pupæ can be found at present. Butterflies are numerous everywhere, and in some fields they rise in clouds before the sweep-net. That the damage from larvæ to the present crop is about over is almost certain. * * * A few farmers cut the crop after it had been stripped by larvæ, and the hay was of such poor quality that it was not even gathered. Much of the hay that was gathered was of such poor quality and some of it was so foul with diseased larvæ that it was of little value.

On July 16 Mr. Packard said that he noticed the "worms" in some numbers in the second crop at cutting time, about the last of May. The real outbreak came in July, however, when the third generation of worms began to eat the third crop of alfalfa. He noticed the bacterial disease in the fields about the first week in July, when a large amount of damage had already been done by the larvæ, but the disease did not become widespread or really effective until after the hot, humid weather of last week.

During the season of 1913 in Arizona the outbreak was heavier in the Salt River Valley than it has been for several years—at least the heaviest since the bureau began its investigations four years ago. The report of the outbreak for this year is taken from the notes of Messrs. R. N. and T. Scott Wilson, both of whom were located at Tempe, in the Salt River Valley, this past year. The greatest amount of damage was done to the fourth crop, although the third crop was considerably reduced. The species reached destructive numbers in the eastern part of the valley, especially in the vicinity of Chandler, earlier than in other parts, so that the third crop was considerably damaged and in some fields totally destroyed. On July 22 Mr. T. Scott Wilson reported considerable damage to a field on Mr. Knepper's ranch, and stated that in large spots, perhaps as large as 50 to 100 yards across, the alfalfa was completely defoliated. On July 29 the same observer states: "Mr. Lang's field, 3 miles north of Chandler, shows more damage than any other field I have seen this year. * * * The entire field is damaged, but on spots where the land is rather poor the alfalfa did not grow as rapidly as in other places, and after irrigation it came up quickly and at this tender stage the worms attacked it, completely stripping it of leaves." Mr. R. N. Wilson had previous to this, on July 25, made a similar but more general note in which he says: "The butterflies are now very numerous, and the larvæ have stripped large patches in several fields. * * * The most serious damage began in the central part of the valley about a week or two weeks later than that described in the foregoing notes and was much more severe. On July 30 Mr. T. Scott Wilson reported very serious damage 6½ miles south of Tempe. This field had about 25 to 50 per cent of the alfalfa destroyed." Then, on August 7: "In Mr. Harmon's field, 1½ miles south of Tempe, there are a great many pupæ and larvæ. The alfalfa is almost completely bare of leaves." And on the same date he noted that Mr. Olsons's alfalfa in an 80-acre field, 1 mile south of town, was almost destroyed. Of course he meant the crop then present. On August 14 he mentions seven different ranches that had almost the entire fourth crop destroyed by Eurymus. A day later Mr. Wilson visited several fields south of Phoenix and found the fourth crop here completely defoliated. It is thus seen that the damage ran into thousands of dollars just to this one crop alone. One can hardly anticipate exactly what would have been the resulting damage had these caterpillars gone on unmolested and produced another generation of butterflies. Fortunately, however, the disease already mentioned appeared at this time and prevented a large percentage, possibly 90 to 95 per cent, from ever reaching the pupal stage.

We thus have a history of the several outbreaks during the last few years in these two larger valleys of southern Arizona and California.

There has also been damage in a smaller way, but just as important to the individual farmer, in other valleys of these States. In the Yuma Valley, near the town by that name, both the writer and Mr. R. N. Wilson have noted the occurrence of the caterpillars in destructive numbers, and in the Buckeye Valley they have made similar observations. Mr. Long reported serious damage in the Buckeye Valley, and in 1913, on the Wessex ranch 2 miles west of the town of Buckeye, Eurymus larvæ entirely stripped a 20-acre field, reducing the alfalfa to mere stubble. In the Gila River Valley, between Thatcher and Safford, Ariz., Mr. R. E. L. Wixon, a deputy State nursery inspector, reports occasional devastation and often entire fields destroyed.

In California Mr. T. D. Urbahns has at various times during 1913 reported outbreaks and very serious damage at several towns in the San Joaquin Valley. We quote the following from his notes: July 9, Corcoran: "Considerable injury where crops were left in field too long." September 13, Tulare: "Farmers generally reported heavy loss to their alfalfa crops from the 'alfalfa worm,' and on some fields the alfalfa was completely destroyed in July, then resuming its growth after the pests had subsided from natural control." September 14, Fresno: "While out a short distance north of town I observed fields yellow with butterflies. The leaves were nearly all badly eaten by the larvæ, of which many were still present." September 15, Dos Palos: "Larvæ present in moderate numbers, but causing much injury." September 16, Merced: "A 10-acre field of alfalfa south of town literally covered by larvæ and adults. Stems had been stripped of their leaves." September 17, Modesto: "West of town farmers consider the alfalfa worm a serious pest to their midsummer crops in July and August. Adults and larvæ were still present in large numbers."

At Indio, in the Coachella Valley, Mr. Bruce Drummond, of the Bureau of Plant Industry, has informed the author that considerable damage is done by these caterpillars and that at times it becomes quite severe.

It is thus seen that what was once considered merely a thing of beauty has now become one of the worst enemies to alfalfa culture, causing between $500,000 and $1,000,000 of damage annually to this crop in these southwestern sections alone. That the energetic and up-to-date farmer can greatly reduce and at times totally eliminate this damage is to be shown in the following pages.

DESCRIPTION.

All stages of *Eurymus eurytheme* have been fully described by Edwards and Scudder, and since this paper is purely economic in purpose, no detailed description will be given, but instead a brief

outline, such as would enable the casual observer to recognize the different forms.

THE ADULT.

The typical wing color of the adults is an orange-yellow with a black outer border above, and a lighter yellow color on the underside with the black outer border wanting. There is a black discal spot in each of the four wings and a double discal spot of orange in each hind wing. The lower surface of the wing is the one noticed when the butterfly is at rest. The male (fig. 4.) may be distinguished from the female (fig. 1) by the fact that the outer border of the wings is solid black in the former, but broken by a line of yellow dots in the latter. A white or albino female form is frequently found with other color markings, the same as in the yellow form. The wing expanse is about 2 inches.

FIG. 4.—The alfalfa caterpillar: Male in the adult, or butterfly, stage. One-half enlarged. (Author's illustration.)

EGG.

The egg (fig. 5) is small, only 0.06 of an inch long, with from 18 to 20 slightly raised longitudinal ridges or ribs broken by cross lines. It is elongated, white when laid, but turning reddish brown after the second day, and is deposited upright, with the basal end attached usually to the upper surface of the leaf.

FIG. 5.—The alfalfa caterpillar: Egg, greatly enlarged. (Redrawn from Scudder.)

LARVA.

The newly hatched larva is a tiny, dark brown, cylindrical object which soon after feeding takes on a green color. Growth is rapid and the larva (fig. 2), after having shed its skin or molted four times, is a little more than an inch in length and is of a dark grass-green color, with a white stripe on each side of the body, through which runs a crimson line. Beneath this stripe on each segment or division of the body is a black spot. There is often an intermediate, narrower, broken, and less distinct white line just above each of the lateral lines. This may be wanting. In some specimens a black or dark green median dorsal line is also present.

PUPA.

The pupa (fig. 6) is yellowish green, with a conspicuous row of black dots just within the margin of each wing pad and three black dots on each side of the abdomen. It is free, having no cocoon, and is found, head up, attached closely by the posterior end to an alfalfa stalk or other support, with the anterior end hanging loosely in a threadlike swing which is joined to the same support.

FIG. 6.—The alfalfa caterpillar: Chrysalis, or pupa. (Author's illustration.)

LIFE HISTORY AND HABITS.

The complete life cycle for this insect averages about 38 days for all generations, the minimum length being about 26 days for the third brood and the maximum 64 days for the first brood. (See Table III.) The time occupied by the different stages is as follows: Egg, 6 days; larva, 24 days; pupa, 7 days, and a resting and feeding period of 1 day following emergence of adults during which copulation takes place. Males usually complete the developmental period several days sooner than the females, and thus pass a longer period between emergence and copulation. Mr. W. H. Larrimer, working at Nashville, Tenn., made some interesting records on the life-cycle periods, as shown in Table I. It will be noted that these records were all made during the months of June and July and correspond with the tables for Arizona showing records made during weather of medium temperature.

TABLE I.—*Rearing records for the alfalfa caterpillar, Nashville, Tenn., 1913.*

Egg laid.	Egg hatched.	Egg stage.	Larva pupated.	Larval stage.	Adult emerged.	Pupal stage.	Food plant.
		Days.		*Days.*		*Days.*	
June 4[1]	June 7	3	June 26	19	July 2	16	Medicago sativa.
4[1]	7	3	July 1	24	8	7	Do.
4	7	3	3	26	10	7	Do.
27	30	3	16	16	23	7	Do.
27	30	3	16	16	23	7	Do.
July 2[1]	July 5	3	22	17	29	7	Do.
2[1]	5	3	23	18	29	6	Do.
2[1]	5	3	28	23	Aug. 1	5	Do.
2[1]	5	3	30	25	6	7	Do.
16[1]	19	3	Aug. 2	14	8	6	Trifolium hybridum.
27	30	3	13	14	20	7	Trifolium repens.
27	30	3	14	15	21	6	Do.
27	30	3	11	12	17	6	Vicia sativa.
27	30	3	12	13	17	5	Do.
27	30	3	11	12	17	6	Do.
27	30	3	15	16	21	6	Pisum sativum.
27	30	3	15	21	21	6	Glycine hispida.
1	4	3	July 28	24	2	6	Trifolium pratense.

[1] Reared under same conditions of light, moisture, temperature, and food supply.

	Days.
Average length of egg stage	3
Average length of larval stage	18
Average length of pupal stage	6½

EGG STAGE.

The egg stage varies under ordinary temperatures from 2 to 15 days, the normal period being about 6 days. The length of the egg stage as observed for the six generations during the season of 1912 is as follows: First generation, 14½ days; second generation, 4 days; third generation, 3 days; fourth generation, 3½ days; fifth generation, 3½ days; sixth generation, 5 days. In the summer of 1913 Mr. T. Scott Wilson had eggs under observation which hatched in two days during the month of August, but with an average mean temperature of 87° F., and this same season Mr. E. H. Gibson, at Nashville, Tenn., observed eggs to hatch in an equally short time, with an average mean temperature of 76° F. Mr. Gibson gathered three eggs on June 5 and noted that the time of oviposition was 3 p. m. He placed these in a box, and at 3 p. m., June 7, the larvæ were found emerging from eggshells. Thus the remarkably short period of 48 hours elapsed from oviposition to hatching.

The eggs are deposited upright, singly, on the upper surface of fresh, green alfalfa leaves. When first deposited they are white in color, but change in a few hours to reddish brown. Just before hatching the upper end becomes light colored or nearly transparent, and the caterpillar gnaws its way out.

LARVAL, OR CATERPILLAR, STAGE.

Upon hatching, the larva makes its first meal on the eggshells, often consuming the whole shell. It then feeds upon the leaf, at first gnawing out very small, tiny spots; but rapidly its appetite increases, and it is soon consuming the entire leaf, veins and all. Observations made by the writer and by Mr. Watts, a former agent of this bureau, show that one larva consumes about 25 to 30 leaves during its lifetime. Its growth increases just as fast as its appetite, and often within 12 days the larva is full grown, having cast its skin, or molted, four times and having passed through five instars, or periods between molts, and increased from less than one-tenth inch to nearly 1½ inches in length. The duration of these various instars (see Table II) is influenced greatly by temperature, and during cold or cool weather they are protracted considerably, so that often the complete larval period will cover a month or even more, the general average period for all temperatures being about 24 days.

The larva in feeding stretches itself along an alfalfa stalk and is often rather hard to find, the green color of its body proving to be exactly the same shade as the alfalfa upon which it is feeding.

TABLE II.—*Duration of larval instars and pupal stages of the alfalfa caterpillar, Tempe, Ariz.*

[The records for 1912 are by the author; those for 1913, by Mr. T. Scott Wilson. Records all made in vials under unnatural conditions.]

Cage No.	Larva hatched.	First molt.	Length of first instar.	Second molt.	Length of second instar.	Third molt.	Length of third instar.	Fourth molt.	Length of fourth instar.	Pupation.	Length of fifth instar.	Length of larval stage.	Adult emerged.	Length of pupal stage.	Sex.	Average mean temperature.
	1912.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*	*Days.*		*Days.*		°*F.*
1	Apr. 7	Apr. 14	7	Apr. 19	5	Apr. 22	3			May 3	11	26	May 13	10	Male	63
2	May 31	June 3	3	June 5	2	June 7	2	June 10	3	(1)						82
3	31		3		5		8		12	June 17	5	17	June 25	8	Female	83
4	June 28	30	2	July 5	2	July 5	3	July 8	3	July 11	3	13	July 16	5	...do	81
5	28	30	2		2		5		7		10	12	15	5	Male	80
6	28	30	2		2		5		8		12	4	14	17	5	Female	81
7	July 25	July 28	3	Aug. 3	6	Aug. 15	12	Aug. 21	6	(1)						84
8	25	28	3	July 31	3		3		5	(1)						85
9	25	28	3		3		2		5	(1)						85
	1913.															
7	June 10	June 14	4	June 18	4	June 20	2			June 27	[2] 7	17				83
12	10	14	4	18	4	20	2	June 23	3		25	15	June 29	4	Male	83
13	10	14	4	(3)	(3)	(3)	(3)	(3)	(3)		25	15	30	5	...do	83
14	11	14	3	(3)	(3)	(3)	(3)	(3)	(3)		25	14	July 1	6	...do	83
15	11	14	3	(3)	(3)	(3)	(3)	(3)	(3)		25	11	(1)			83
17	11	14	3	June 18	4	June 20	2	June 21	1		25	4	14	June 30	5	Male	83
18	11	15	4	18	3	20	2	22	2	(1)						83
26	12	17	5	19	2	(3)	(3)	(3)	(3)	June 28		16	(1)			83
32	12	16	4	18	2	(3)	(3)	(3)	(3)		25	13	July 2	7	Male	83
34	12	15	3	18	3	June 20	2	June 23	3		27	4	15	1	(1)	83

[1] Died.

[2] Combined length, fourth and fifth instars.

[3] No record.

PUPAL, OR CHRYSALIS, STAGE.

As has been stated before, the pupæ are found hanging, head up, attached to alfalfa or other stems, and as their color blends with their environment they are often hard to see and will be overlooked unless searched for. Often, too, instead of pupating on a bare stem the larvæ will crawl to a leafy stem and pupate there, thus protecting themselves still further from their enemies and from the rays of the sun. The average length of the pupal period for ordinary field temperatures is about 7 to 10 days, but varies considerably with the temperature. Records made by the writer at Tempe, Ariz., from March to September, 1912, showed a variation of from 5 to 10 days, and records made at the same place in 1913 showed a variation of from 5 to 7 days, while Mr. W. H. Larrimer, at Nashville, Tenn., secured records during the summer of 1913, from July 2 to August 21, in which the pupal stage varied from 5 to 7 days, averaging for 18 specimens 6⅓ days. There is no doubt that the pupal period may be lengthened to 12 or 15 days, or even more, if the temperature is low enough.

ADULT, OR BUTTERFLY, STAGE.

The process of emergence from the pupa is one of short duration and usually occurs early on a bright morning. The butterfly crawls up a stalk, soon spreads and dries its wings, and is off looking for bloom upon which to feed. Copulation often takes place within a day or sometimes on the same day, and the female begins ovipositing on the day following. A large number of eggs is usually laid by one female. In the Southwest the number per individual is greater during spring and fall than during the extreme hot weather. At Tempe never more than 200 eggs were recorded for one female, the number often being as low as 50. At Tempe, also, the total number was often deposited in a single day, while specimens sent to New Hampshire deposited as many as 500 during a laying period of 11 days. This shows the relation of temperature to egg production.

The sending of gravid female moths from Tempe, Ariz., to Prof. John H. Gerould, at Hanover, N. H., a railroad trip of several days, was a matter of interest and shows well the hardiness of the butterflies. The butterflies were placed inside a tin box securely lined with moist blotting paper, and the box was then wrapped carefully and mailed. Vigorous specimens were secured and only a few to a box. While not every attempt was successful, a great many were so. Through the kindness of Prof. Gerould I quote from a letter written October 7, 1913:

> The third female from Arizona produced from one laying of eggs 214 males and 206 orange-yellow females. She was mailed at Tempe on June 6 and re-

ceived at Hanover in strong active condition on June 10. She began to lay on June 11 and continued until June 22. Her 420 adult offspring represent only a part of her caterpillar progeny, for, besides the loss through disease and accident, 15 pupæ succumbed to excessive cold and other unfavorable conditions in a refrigerator while undergoing an experiment to determine the effect of cold upon color. Probably 500 eggs were laid.

The proportion of males to females in Arizona is about 2 to 1, but Gerould, in New Hampshire, finds them about equal. In the field at Tempe one will always be impressed with the superabundance of males. This difference in the proportion of the sexes as between Arizona and New Hampshire is probably due to the fact that in Arizona the intestinal disease kills a large number of the larvæ; and since males develop a few days sooner than females, it is likely that the majority of the larvæ killed would have developed into females, while those escaping the disease become males. In New Hampshire Prof. Gerould is often able to rear over 90 per cent from egg to adult in confinement, while at Tempe it is rare that 25 per cent of the eggs are reared. In a blooming alfalfa field the percentage of males to females is still higher, owing to the fact that females after feeding and mating leave this older alfalfa to seek new growth. In searching out this tender growth for egg deposition it seems as if they knew that if their eggs were laid on the older alfalfa it might be cut before the larvæ could mature. One can tell at a glance an ovipositing female. She has a hesitating flight and at intervals will drop down for a moment on an alfalfa leaf and, depositing an egg, will flutter on, soon repeating the operation and depositing as many as four or five eggs per minute.

Among the yellow butterflies in a field one notices many white or albino forms. These are of the same species as the yellow ones and, according to Prof. Gerould,[1] are merely color phases, as he has shown to be the case in *Eurymus philodice* (Godart).

FEEDING HABITS OF THE BUTTERFLIES.

The butterflies of *Eurymus eurytheme* feed upon nectar from the blossoms of a great many plants. Over a blooming alfalfa field one can often see them by the millions, visiting the blossoms and extracting the nectar therefrom. This habit has occasioned many remarks, farmers quite often being under the impression that these butterflies were producing some direct results upon the growth of the alfalfa crop. The bee-keeping farmer usually insists that they are robbing his bees by taking nectar that belongs to them. In Circular 133 of the Bureau of Entomology, published in 1910, the writer ventured the remark, since he had witnessed the tripping of the pollen trigger

[1] Gerould, J. H. The inheritance of polymorphism and sex in *Colias philodice*. Amer. Nat., v. 45, p. 257–283, May, 1911.

of alfalfa bloom by this butterfly, that possibly its feeding habits might be of some benefit in assisting pollination. As this statement occasioned some comment, further observations were made upon the butterflies during three consecutive years, but not another instance of tripping was noted. It seems, therefore, that in the cases observed, the trippings were effected accidentally by the feet. As these instances are probably exceptional it is not likely that the butterflies exert any material influence on seed production. However, the relation of bees and alfalfa to butterflies and alfalfa seems to be a complex one. Hermann Müller,[1] in 1873, came to the conclusion that butterflies probably effect explosion and cross-fertilization, while C. V. Piper,[2] in 1909, in his Report of the Committee on Breeding Forage Crops, gives the records from a considerable number of well-known plant breeders, no two of whom seem to agree as to the exact relation of butterflies to alfalfa pollination, but the majority of whom think that the butterflies exert no influence.[3] Whether the butterflies rob honeybees of their just food is a question. Prof. Cockerell[4] states, in 1899, that * * * "butterflies, sucking the nectar, but making no honey, must interfere with the success of the bees, especially when they become very numerous." As mentioned above, this robbing of the bees by butterflies is a common belief among beekeepers and has been suggested to the author many times.

NUMBER OF GENERATIONS.

Mr. W. H. Edwards[5] reports two broods of this species in the mountains of northern Colorado, the adults of which appear in June and again in the latter part of July and in August. In Nebraska and Illinois, according to the same author, three broods are recorded, while in the lowlands of California he reports the insect as being triple or quadruple brooded. Mr. J. Boll,[6] in 1880, reports four broods in Texas, and this, too, during a short season, for he

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[1] Müller, Hermann. Die Befruchtung der Blumen durch Insekten, Leipzig, 1873, p. 228–229.

[2] Piper, C. V. Report of the committee for breeding forage crops. Alfalfa and its improvement by breeding. Amer. Breeders' Assoc., v. 5, 1909, p. 94–115.

[3] Since this manuscript was submitted for publication, Bulletin No. 75 of this department, dated Apr. 8, 1914, treating of Alfalfa Seed Production; Pollination Studies, by Prof. C. V. Piper and his assistants, has been published.

In this document it is shown that tripping of alfalfa flowers may be automatic as well as effected by insects or other external agents. The authors state that this automatic tripping takes place more frequently in hot sunshine, although humidity is doubtless a factor. Also the statement is made that this automatic tripping, with consequent self-pollination, probably results in the setting of as many pods as does tripping by insect visitors, at least in the West.—F. M. W.

[4] Cockerell, T. D. A. Some insect pests of Salt River Valley and the remedies for them. Ariz. Agr. Expt. Sta. Bul. 32, p. 273–295, Dec., 1899.

[5] Edwards, W. H. The Butterflies of North America, second series, Boston, 1884, Colias IV.

[6] Boll, J. Ueber Dimorphismus und Variation einiger Schmetterlinge Nord-Amerikas. Deut. Ent. Ztschr., Bd. 24, Heft 2, p. 241–248, 1880.

states that the species æstivates during the summer months from June to November.

In the year 1910, in the Imperial Valley of California, there were four distinct generations up to July 15. The fourth generation, however, was almost entirely exterminated by the disease before mentioned, and, following this, later generations became so largely confused that it was impossible to separate them, since, unfortunately, no series of generation cages were then in use for this purpose. The first generation in 1913 covered the period from March 15 to April 30; the second generation from May 1 to May 28; the third generation from May 28 to June 20; and the fourth generation from June 20 to July 15. It seems quite probable that there were at least three generations during the rest of the season. As shown in Table III, during the year 1912, at Tempe, Ariz., there were six generations, adults of hibernating forms appearing in March and adults of the fifth generation disappearing in October, while a few adults of the sixth generation appeared during warm periods of the winter months.

TABLE III.—*Generations of the alfalfa caterpillar, Tempe, Ariz., 1912.*[1]

Generation.	Eggs laid.		Eggs hatched.		Length of egg stage.	Larva pupated.	Length of larval stage.	Adults issued.[2]	Length of pupal stage.	Total developmental period.	Number issued.	Average mean temperature.
	Date.	Number.	Date.	Number.								
	1912.				*Days.*		*Days.*		*Days.*	*Days.*		°*F.*
1st...	Mar. 24	Many.	Apr. 7 8	12 31	14 15	May 11	34	May 19	8	56	17 females... 30 males...	63.5
2d...	May 27	36	May 31	36	4	June 18	18	June 24	6	28	2 females... 1 male...	83.75
3d...	June 25	Many.	June 28	Many.	3	July 13	15	July 19	5	23	3 females... 2 males...	86.5
4th...	July 22	Many.	July 25	Many.	3½	Aug. 12	18	Aug. 19	7	28½	1 female... 1 male...	84.5
5th...	Aug. 23	6	Aug. 26	6	3½	Sept. 9	16	Sept. 19	10	29½	3 females... 3 males...	80.0
6th...	Sept. 28	Many.	Oct. 3	Many.	5	Nov. 18	45	These hibernated.				64.0

[1] The first half of this table does not give duration of time elapsing between emergence and oviposition.
[2] Date here is the day the last ones issued.

PERIODS AND DURATION OF GENERATIONS.

	Days.
First generation, Mar. 24 to May 27	64
Second generation, May 27 to June 25	29
Third generation, June 25 to July 22	26
Fourth generation, July 22 to Aug. 23	33
Fifth generation, Aug. 23 to Sept. 28	38½
Sixth generation, Sept. 28 to pupæ in hibernation.	

Mr. T. Scott Wilson, working at Tempe, secured records during the year 1913 of three distinct generations from late March to the latter part of July, his observations thus corresponding fairly well with those of the writer during the previous year. The dates of the three generations were as follows: First brood, March 27 to May 20; second brood, May 20 to June 23; and third brood, June 23 to

July 23. Following this the intestinal disease attacked the larvæ so generally that Mr. Wilson found it impossible to continue generation records. Nevertheless, he states in his field notes that a fourth generation was out by the latter part of August. We thus see that there are in the colder sections of the country two generations annually and in the extreme warmer sections at least six and possibly more generations each year.

FOOD PLANTS.

Alfalfa seems to be the favorite food plant, but there are quite a number of others. The two buffalo clovers, *Trifolium reflexum* and *T. stoloniferum*, were probably the original native food plants. For some years the species was thought not to live upon red clover (*T. pratense*), but Mr. E. H. Gibson, at Greenwood, Miss., and Mr. W. H. Larrimer, at Nashville, Tenn., proved conclusively that it does attack red clover. They collected both eggs and larvæ from red clover and reared them to adults. During the summer of 1913 the writer collected the larvæ feeding upon few-flowered Psoralea (*Psoralea tenuiflora*) at Koehler, N. Mex., and Mr. Larrimer, at Nashville, made some interesting experiments, besides those on red clover. Using larvæ that hatched indoors, he reared them from the following plants that had not already been reported as food plants: Alsike clover (*T. hybridum*), soja bean (*Glycine hispida*), Canadian field peas (*Pisum sativum*), and hairy vetch (*Vicia sativa*). Repeated attempts to rear them on cowpeas (*Vigna sinensis*) resulted in failure. He says: "On hairy vetch they seemed to thrive exceedingly well and completed their life history in a shorter period than on any other food plant." In July, 1910, the writer found larvæ feeding on sweet clover (*Melilotus alba*), which, strangely enough, they seemed to prefer to a patch of alfalfa growing close by. Eggs were observed to be very numerous upon the leaves of the sweet clover at the same time. Besides alfalfa and the buffalo clovers, Scudder[1] has recorded Hosackia, ground plum (*Astragalus caryacarpus*), and *A. crotalariæ* as food plants. The adults visit blooming plants for nectar, and they have been reported, doubtless erroneously, as feeding upon many of these. The butterfly is known to oviposit on toothed medicago or bur clover (*Medicago hispida*). Mr. E. H. Gibson, at Greenwood, Miss., reported females ovipositing on coffee weed (*Sesban macrocarpa*), which they curiously preferred to red clover growing near by.

[1] Scudder, S. H. The Butterflies of the Eastern United States and Canada, v. 2, Cambridge, 1889, p. 1132.

HIBERNATION.

According to earlier records by Edwards and those a little later by Scudder, which treat of the species in its northern rather than in its southern range, the alfalfa caterpillar hibernates as larvæ and adults, whereas G. H. French,[1] in his revised edition of Butterflies of Eastern United States, reports the species as hibernating as chrysalids. The writer has observed the species hibernating in all three forms, if it could really at all times be termed hibernation. Hibernating chrysalids were found upon weed and alfalfa stems by the writer at both Tempe, Ariz., and El Centro, Cal., and at Wellington, Kans., Mr. Kelly reported the finding of hibernating pupæ beneath fence rails. Just a few larvæ have been collected by sweeping at various times during the winter season at Tempe. During the last week in January, 1912, a single larva was taken, while in January, 1913, Mr. R. N. Wilson took a third-instar larva less than two weeks after a very severe cold spell, i. e., severe for the Salt River Valley, a temperature of 13° F. having been recorded on two successive nights. On warm days adults have been observed in flight several times during the winters when the species was under observation. In 1910 adults were taken at Tempe early in December, and Mr. W. E. Packard took them during the third week in December at El Centro, Cal. In the winter of 1911–12 adults were seen on the 20th of December and again in the middle of January. Larvæ have been collected in January and, pupating within a few weeks, have issued early in March. Pupæ collected in December have issued in February, but adults have never been noted to deposit eggs during the month of January. It is thus seen that at times hibernation amounts to nothing but a prolongation of one of the three stages, the usual activity for each respective stage being resumed on warm days that occur during the hibernation period.

According to Boll[2] the species æstivates in Texas as larvæ during the dry period in summer when the food supply has become exhausted. The writer has never witnessed the æstivation of this species in the Southwest. In fact, it has always occurred in most abundance during the hotest months of the year, notably July and August. Other bureau records likewise show no report of æstivation. It seems safe to assume that the change in habit from that early reported by Boll in Texas is due to recent irrigation of tracts of land well distributed over the arid regions of the Southwest. Originally the species had to æstivate during summer when clovers

[1] French, G. H. The Butterflies of the Eastern United States. New and rev. ed., Philadelphia, 1900, p. 130.

[2] Boll, J. Ueber Dimorphismus und Variation einiger Schmetterlinge Nord Amerikas. Deut. Ent. Ztschr., Bd. 24, Heft 2, p. 241–248, 1880.

were dried up, but now, in the thrifty-growing alfalfa fields of this once arid country, it finds a place to continue its activity throughout the summer, and, as has been mentioned before, it is this very change that has enabled the species to become the pest that it is to-day.

NATURAL CHECKS TO THE SPECIES.

Were it not for the fact that this species is preyed upon by a great many natural enemies it would indeed prove a much more serious pest than it is at the present time. Parasites and predaceous insects, fungous and bacterial diseases, birds, toads, and even domestic fowls, all play a large part toward keeping the species well within bounds during certain seasons of the year.

In 1889 Scudder[1] said: "Strange to say, not a single parasite has been reported to attack this common insect." However, the author and others, during the past three years, have reared as many as nine parasites from the various stages of this butterfly, and some of these at times are quite numerous. An example of the extent of parasitism may be gleaned from the following record of a collection of 154 pupæ made at Tempe, Ariz., on August 26, 1912:

	No. of pupæ.
Infested by chalcid parasites	82
Partially eaten by *Heliothis obsoleta*, etc	28
Rotten from intestinal disease	37
Infested by tachinid parasites	6
Alive and healthy	1
Total	154

This, of course, was an exceptional collection, but often collections were made from which as few as 5 per cent of the pupæ were reared to adults. The percentage of parasitism usually reaches the maximum during the month of August, so that rarely is much damage done by the caterpillar after that time.

PARASITES OF THE EGGS.

Only one egg parasite of *Eurymus eurytheme* was found. This is the very common *Trichogramma minutum* Riley (fig. 7), which is known as an egg parasite of a great many species of insects. In its relation to eggs of this species it was first found by Mr. Harry Newton, of the Bureau of Entomology, who was working at Tempe, Ariz., during the summer of 1913. On July 26 he found three eggs which were very dark in color, and two days later three of the tiny parasites issued from one of these. Two days previous to Mr. Newton's collection Mr. T. Scott Wilson collected 100 eggs. From three

[1] Scudder, S. H. The Butterflies of the Eastern United States and Canada, v. 2, Cambridge, 1889, p. 1132.

of these parasites issued several days later, or 3 per cent. On July 28 Mr. Newton, encouraged by his first efforts, collected 31 eggs that appeared to be parasitized. Twenty-six of these produced, in the course of five days, 76 parasites, or nearly 3 to each egg. Seventeen freshly laid eggs were exposed to female parasites by Mr. Newton on August 1, and on August 8 eight of these produced 24 adult parasites, showing the length of the combined egg, larval, and pupal stages to have been seven days. Nine failed to be parasitized, and one produced 5 parasites in six days. On August 16 Mr. Wilson collected 19 eggs, 60 per cent of which were parasitized.

FIG. 7.—*Trichogramma minutum*, a parasite of the eggs of the alfalfa butterfly, in act of oviposition in an egg of the brown-tail moth (*Euproctis chrysorrhœa*). Greatly enlarged. (From Howard and Fiske.)

It is thus seen that this tiny parasite is of considerable benefit in reducing the numbers of the alfalfa caterpillar. From the records it seems that the increase of the parasites from July to August was quite rapid. The fact that the life cycle is of so short duration is partially responsible for this, as it doubtless gives a chance for two broods of parasites upon the eggs of one generation of Eurymus.

HYMENOPTEROUS PARASITES OF THE CATERPILLARS AND CHRYSALIDS.

Four species of hymenopterous parasites of the caterpillars and chrysalids were found. Specimens of a Limnerium were reared

FIG. 8.—*Limnerium* n. sp., an ichneumonid parasite of the alfalfa caterpillar: Adult. Greatly enlarged. (Original.)

by the author at El Centro, Cal., in 1910, and what is supposedly the same species was reared in considerable numbers by Mr. L. P.

Rockwood at Salt Lake City in the summer of 1913 and has since been determined by Mr. A. B. Gahan, of this bureau, as *Limnerium* n. sp. (fig. 8). Mr. Rockwood found these parasites of material benefit in the suppression of outbreaks in Utah and always reared them from young and only partially grown larvæ. At Salt Lake City, during the summer of 1913, he also reared a goodly number of a small hymenopteron, *Apanteles* (*Protopanteles*) *flavicombe* Riley. This species is gregarious, but was not found to be sufficiently numerous to exert any marked effect upon the abundance of Eurymus. The common *Chalcis ovata* Say (fig. 9) was first reared from this species by the writer in 1910, at El Centro. Only one specimen was secured, but in 1912 the author reared many adults, and in 1913 the Messrs. Wilson reared adults from pupæ collected in both Arizona and California.

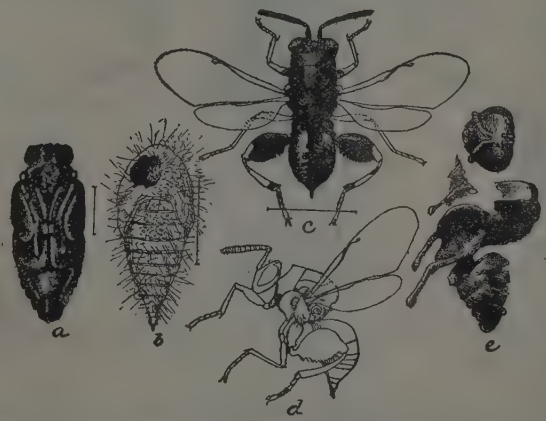

FIG. 9.—*Chalcis ovata*, a parasite of the pupa of the alfalfa caterpillar: *a*, Pupa; *b*, parasitized pupa of tussock moth (*Hemerocampa leucostigma*); *c*, adult; *d*, same in profile; *e*, pupal exuvium. Enlarged. (From Howard.)

PTEROMALUS EURYMI GAHAN.

The three parasites just mentioned are of minor importance, but the fourth is of great assistance in suppressing outbreaks of the alfalfa caterpillar. It is a new species, recently described by Mr. Gahan [1] as *Pteromalus eurymi* (fig. 10). Mr. H. T. Osborn, at Wellington, Kans., in September, 1910, reared 40 specimens of this species from a pupa of Eurymus, but the specimens were put into alcohol and not determined until November, 1913. When, therefore, Mr. R. N. Wilson secured a parasitized pupa in December, 1911, and

[1] Gahan, A. B. New Hymenoptera from North America. Proc. U. S. Nat. Mus., v. 46, p. 431–443, 1913. "*Pteromalus eurymi*, new species," p. 435–436.

reared this parasite, it was believed to be the first rearing record. During the following summer the parasites were so numerous that it was hard to understand why they had not been discovered before. Collections of pupæ of Eurymus were made by the writer in August,

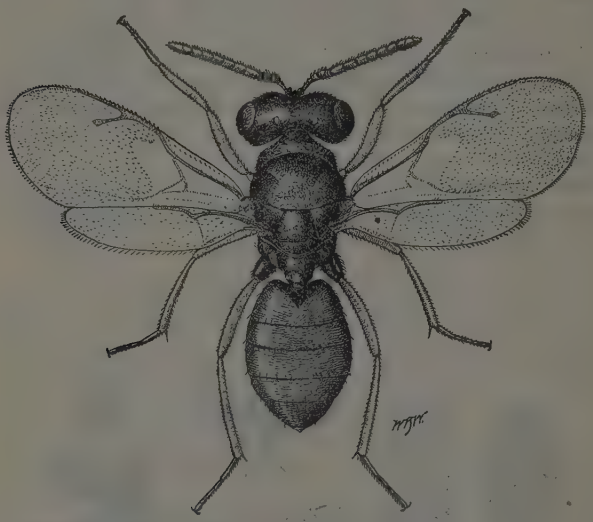

FIG. 10.—*Pteromalus eurymi*, a parasite of pupæ of the alfalfa caterpillar: Adult. Greatly enlarged. (Original.)

1912, and showed that 49 per cent were parasitized by this species. The record follows:

TABLE IV.—*Parasitism of pupæ of the alfalfa caterpillar by Pteromalus eurymi.*

Date	Pupæ collected.	Infested with Ptero-malus.	Per cent infested.
1912.			
Aug. 5	65	26	40
Aug. 14	39	17	43+
Aug. 19	11	7	63+
Aug. 26	154	82	53
Total and average	269	132	49

This insect thus seems to be exerting a larger influence than any other parasite toward the control of the alfalfa caterpillar.

In 1913 Mr. T. Scott Wilson did not find it nearly so numerous in the Salt River Valley as was the case the year before. Just why this was so, it is hard to say. The extremely cold weather during the

preceding winter may have killed the hibernating Pteromalus larvæ (fig. 11). In the same year Mr. R. N. Wilson found the species quite numerous in the Imperial Valley of California. As many as 20 per cent of the Eurymus pupæ were parasitized by it.

This parasite seems to be distributed over a considerable area, for, besides being present in Arizona and California and, as stated, at Wellington, Kans., it has been reared during the season of 1913 and found to be quite abundant at Salt Lake City, Utah, by Mr. Rockwood, and at Nashville, Tenn., specimens were raised by Mr. Larrimer from a single pupa of Eurymus.

It seems almost certain that this parasite winters as a larva within the pupal shell of the host. The first lot collected in a pupa of the alfalfa caterpillar in December were discovered as larvæ in January and soon thereafter turned to pupæ (fig. 12), issuing as adults in March. The eggs are laid in pupæ of Eurymus, from 40 to 114 parasites developing in one pupa. About 80 to 90 per cent of these are females and the rest males, and the adults issue from one or more tiny holes in the pupa of their host. (See fig. 13.)

FIG. 11.—*Pteromalus eurymi:* Larva. Greatly enlarged. (Original.)

FIG. 12.—*Pteromalus eurymi:* Pupa. Greatly enlarged. (Original.)

FIG. 13.—*Pteromalus eurymi:* Adults issuing from chrysalis of alfalfa caterpillar. Enlarged nearly three diameters. (Original.)

The combined length of the egg, larval, and pupal stages in the warmer weather of August is from 12 to 15 days, while the pupal stage was found to cover 4 days in the month of August and 12 to 15 days in February, the variation being due to differences of temperature. Thus several generations are possible each season, and thus, with abundant egg production and high percentage of females, gives rise to a rapid increase in the number of parasites, so that by late August the multiplication of the host species is checked.

DIPTEROUS PARASITES.

Three tachinid flies, determined by Mr. W. R. Walton, of this bureau, have been reared from the larvæ and pupæ of this caterpillar. *Phorocera claripennis* Macq. (fig. 14) is the most important of these, its wide distribution and abundance of alternate hosts causing it to be always on hand. In 1910 at El Centro, Cal., the writer observed as many as 15 per cent of Eurymus larvæ with eggs of this species attached to them; while in 1913 Mr. T. Scott Wilson, at Tempe, Ariz., observed as many as 50 per cent of larvæ with eggs upon them, and in some cases there were as many as five or six to one caterpillar. Of course a great many of these eggs are shed in molting, but a majority of them hatch, and the maggot, entering the Eurymus larva, kills it in a short time. *P. claripennis* has been reared from this species at the following other places: Salt Lake City, Utah (E. J. Vosler and L. P. Rockwood); Wellington, Kans. (H. T. Osborn); Greenwood, Miss. (E. H. Gibson); Nashville, Tenn. (W. H. Larrimer). Three specimens of *Frontina archippivora* Will. were reared from a larva and pupa collected at El Centro, Cal., by Mr. R. N. Wilson, and a single specimen of the same species was reared by Mr. Rockwood at Salt Lake City, while at El Centro a single specimen of *Masicera* sp. was reared by the writer.

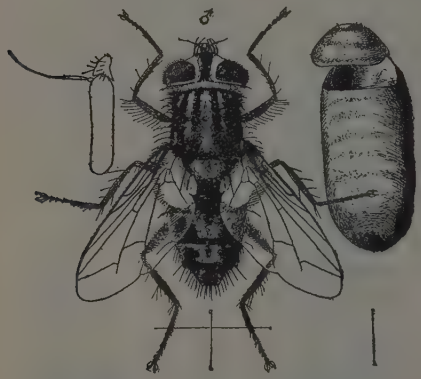

FIG. 14.—*Phorocera claripennis*, a parasite of the alfalfa caterpillar. Adult and enlarged antenna of same; puparium. Enlarged. (From Howard.)

FIG. 15.—*Aphiochæta perdita*, a phorid parasite of the pupa of the alfalfa caterpillar. Greatly enlarged. (Original.)

Besides these tachinid parasites, another small dipteron was discovered by Mr. T. Scott Wilson to be parasitic upon the pupæ. This was a small brown phorid (fig. 15) which has been determined by Mr. J. R. Malloch as *Aphiochæta perdita*, a species recently de-

scribed by him[1] as new. This is supposedly a new record of habit for this species, but according to Mr. Wilson it was reared time and again from pupæ which were alive when collected; thus the flies could not be acting as scavengers, but must have been true parasites.

OTHER INSECT ENEMIES.

A large green caterpillar, known as the bollworm, *Heliothis obsoleta* Fab. (fig. 16), which can be distinguished from the alfalfa caterpillar because it is of a lighter green color, about one-fourth larger, hairy, and rough in appearance rather than smooth, with three black lines traversing its body lengthwise, is quite prevalent in the Imperial and Salt River Valleys, and is often mistaken for the alfalfa caterpillar by many farmers. As observed by the writer, and later by Mr. T. Scott Wilson, it was found to do very little damage to alfalfa, but to be a ravenous enemy of the alfalfa caterpillar, never eating alfalfa as long as it could find the larvæ or pupæ of Eurymus. Messrs. E. O. G. Kelly and T. H. Parks noted this species at Wellington, Kans., in the summer of 1909, and reported it as being of a predaceous habit.[2]

FIG. 16.—Bollworm (*Heliothis obsoleta*), an enemy of the alfalfa caterpillar. Twice natural size. (Author's illustration.)

FIG. 17.—Chrysalis of alfalfa caterpillar that has been eaten out by a bollworm. Enlarged about two diameters. (Original.)

The writer observed a bollworm larva to eat five large larvæ of Eurymus during a single day, and both the writer and Mr. T. Scott Wilson counted dozens of pupal cases with the contents eaten out (fig. 17) and many times with the Heliothis larva still feeding upon and devouring the pupæ. Mr. Wilson, on July 15, 1913, remarked in his field notes that "Heliothis was observed in great numbers feeding upon Eurymus pupæ, and in a few instances on Eurymus larvæ. The Heliothis makes a hole in the side of the pupa, through which he puts his head and eats out the contents of the pupa." The writer has observed the end of the abdomen eaten off the pupa; again, an opening would be made on the side, often the entire side being destroyed.

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[1] Malloch, J. R. The insects of the dipterous family Phoridæ in the United States National Museum. Proc. U. S. Nat. Mus., v. 43, p. 459–460, 1912. "*Aphiochæta perdita*, new species," p. 459.

[2] This cannibalistic habit has also been observed in Texas by Quaintance and Brues. (U. S. Dept. Agr., Bur. Ent., Bul. 50, p. 79–80, 1905.)

The malachiid beetle, *Collops vittatus* Say (fig. 18), is rather numerous in the alfalfa fields of Arizona and was suspected of bearing some relation to Eurymus. Mr. T. Scott Wilson found both adults and larvæ feeding upon pupæ of the alfalfa caterpillar. He observed as many as 20 beetles feeding upon as many pupæ in a single day. This beetle seems to feed upon either live or dead Eurymus larvæ and pupæ and does not appear to have much choice between the two. It attacks a pupa or larva and, piercing it, sucks the juices that exude. In this way a hole is gradually made in the host, which, of course, is killed. Being small, the beetle does not consume much of its prey, but wanders off, and the next time it is hungry it attacks a new pupa or larva and thus kills many. Larvæ were taken in the act of feeding upon Eurymus pupæ, placed in vials, and reared to adult Collops.

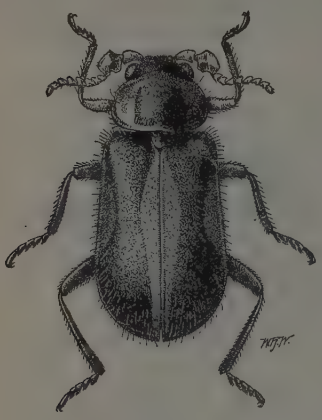

FIG. 18.—*Collops vittatus*, a beetle that preys upon the alfalfa caterpillar. Greatly enlarged. (Original.)

Two species of ants, *Pogonomyrmex barbatus* Smith and *Cremastogaster lineolata lævius-cula* var. *clara* Mayr (?) were observed to attack Eurymus larvæ and kill them. Several species of robber flies have been observed to catch the adult butterflies and feed upon them. The writer took *Proctacanthus milbertii* Macq. with a butterfly in its claws, and Mr. H. E. Smith, at Koehler, N. Mex., observed the butterflies being carried off by *Stenopogon picticornis* Loew (fig. 19).

FIG. 19.—*Stenopogon picticornis*, a robber fly that preys upon alfalfa butterflies. Not quite natural size. (From C. N. Ainslie.)

A FUNGOUS ENEMY.

A fungus was found to attack the pupæ in the Salt River Valley in 1912. This is sometimes quite common, but never abundant, although more prevalent about August than at other times, probably owing to higher humidity. Dr.

Flora W. Patterson, of the Bureau of Plant Industry, has determined this as a Fusarium. In her letter she says: "The fungus, which bears strong evidence of being parasitic, has quite filled the body cavity and is either a Fusarium or Microcera," and states that the majority of similar fungi are reported upon scale insects. Later she says, "Cultures of the above fungus, parasitic upon *Eurymus eurytheme*, have developed in the most satisfactory manner, and it is probably an undescribed parasitic Fusarium."

A DISEASE.

As has been mentioned earlier in this paper, a disease which is probably bacterial and resembles flacherie of the silkworm is quite common upon larvæ and pupæ of Eurymus. At times, evidently during periods of higher humidity accompanied by warm weather, as in July and August, it becomes so widespread as to kill a great majority of a brood and often nearly annihilates it. This disease is by far the greatest natural check against which the alfalfa caterpillar has to contend and is one of the most important factors looking toward its control.

The dead worms, which are nothing but soft decayed masses found hanging to the alfalfa stalks, are sometimes so numerous as to make sweeping with an insect net impossible, the net in a few sweeps becoming so foul as to render other insect specimens of little value. The disease has proved a great detriment to the successful carrying on of life-history experiments and the rearing of parasites, owing to the fact that large percentages of larvæ taken to the laboratory and confined often die from it. Frequently, where a hay crop is not totally destroyed by a brood of caterpillars before they are killed by this disease, the decayed remains on the hay become so foul as to render the hay quite unpalatable for horses and hence of low value.

As has been suggested, the development of the diseased condition in either larvæ or pupæ—for it attacks both—depends largely upon moisture. The disease is present at all times, and a few larvæ from each brood are killed, but it is only when a period of high humidity accompanied by warm weather occurs that it becomes so prevalent as to attack the worms in large numbers. It has been found that at certain times these conditions of moisture may be produced artificially by irrigation, and, as is discussed in a later paragraph, the disease, thus fostered, is utilized as a factor in controlling the pest. That the disease does not at all times keep the caterpillar in check is doubtless due to the dry climate of these southwestern countries, and a comparison of the conditions in the Imperial Valley of California with those in the Salt River Valley of Arizona supports this view. The Imperial Valley is unique in location, being below sea

level and having an average annual rainfall of probably less than 2 inches, while the Salt River Valley has an elevation of some 1,200 feet and an annual rainfall of about 8 inches. A study of the outbreaks of Eurymus in the two valleys shows them to vary inversely with the rainfall. In the dryer Imperial Valley the outbreaks are more numerous and severe and the resultant damage is greater than in the Salt River Valley with its greater rainfall and its longer period of humid weather during the hot summer months.

The worms when first attacked take on a lighter green color and become sluggish; but in a few hours they change to a brownish black and melt down into a decaying mass. A first sign of the breaking down of tissues may often be noted when the worm is still active, a slight exudation at some small broken place, usually in front; and the writer has noted specimens with the anterior end blackened and the posterior end still slightly moving, showing that life was not yet extinct. The attack upon a pupa is similar, except that the stronger pupal covering usually prevents the melting down of the specimen, and later the decayed contents of the interior dry up, leaving the empty black shell still intact.

BIRDS AND DOMESTIC FOWLS.

Few records are available showing the relation of wild birds to the alfalfa caterpillar. Several times the writer has observed birds with larvæ in their bills, but he was unable to capture these, not having the necessary firearms. Domestic fowls, however, play an important part in the history of this insect. In alfalfa adjoining farmhouses where chickens or turkeys have the run of the field one rarely finds alfalfa caterpillars in numbers, whereas fields adjoining chicken lots inclosed with wire fence, keeping the poultry out of the alfalfa, suffered severe damage. In Mr. R. N. Wilson's notes for 1912 he reports that "Mr. Carlos Stannard, living 4 miles northeast of Glendale, Ariz., killed a young rooster and found 24 Eurymus larvæ in the rooster's crop." Mr. T. Scott Wilson was informed by Mr. Everett, living near Tempe, that he and his wife had found a dozen larvæ in a chicken's crop, the chickens having access to an alfalfa field growing near the house. By the same observers, turkeys have been noted feeding greedily upon the larvæ, a flock in traveling across an alfalfa field eating hundreds of them. Mr. T. Scott Wilson, on July 21, 1913, at Chandler, Ariz., made the following note:

> I observed one dozen turkeys in a half acre of alfalfa on the lots of the United States power house feeding upon Eurymus larvæ. The alfalfa is about 12 inches high and is tender. I find only a few Eurymus feeding upon this alfalfa, while in a large field just across the fence the alfalfa is almost destroyed, except that in that portion next to the house where the tur-

keys likewise feed there are few Eurymus to be found, and consequently no damage. * * * I also observed several chickens feeding upon Eurymus larvæ.

From these observations it is seen that chickens may be utilized in small fields to keep down the numbers of alfalfa caterpillars, and that turkeys, because of their roving nature, can be used to advantage in larger fields. Mr. Charles Springer, of Cimarron, N. Mex., informs the writer that he hires a boy to herd an immense flock of turkeys on the range, so that they may feed upon the grasshoppers destroying the grama grass and other range grasses (see Pl. I, fig. 2, p. 4). It seems that the same method could be employed in outbreaks of the alfalfa caterpillar.[1] There is always a good demand for fattened turkeys, and with the cheap labor of a Mexican boy for herding the turkeys, if this additional expense is really necessary, the caterpillars could be kept within bounds at a very small cost per acre, or possibly even at a profit.

OTHER ENEMIES.

Quite a few observations have been made upon the food habits of toads. These batrachians have been found to feed upon both adults and larvæ of Eurymus, as many as 45 adults and 1 larva having been found in a single stomach on one occasion, while on another 15 Eurymus larvæ were found, besides 4 of Heliothis, 3 geometrids, 3 larvæ not classified, a cricket, and the remains of a few beetles. As toads are quite numerous throughout the alfalfa fields of the Salt River Valley, they must exert a considerable influence toward the suppression of outbreaks of the alfalfa caterpillar.

THE CONTROL OF THE ALFALFA CATERPILLAR.

PASTURING VERSUS HAYING.

It was first noted by the writer in 1910, during his early study of the subject, that fields in pasture are never troubled as much by the alfalfa caterpillar as are haying fields. Since then this has been clearly verified, not only by the writer but by others connected with the work. On July 14, 1913, Mr. R. N. Wilson makes the following note, which bears out this statement:

> Many of the fields about El Centro have been cut recently and so show nothing now as to Eurymus conditions. Many are also being pastured, and in these the caterpillar attack is slight. In some fields which have not been either pastured or cut the damage is considerable.

There are several factors which explain this. At first it was thought to be owing entirely to the lack of bloom for the butter-

[1] Of course care should be exercised not to allow the turkeys in the alfalfa after it has become too high and rank, nor should too great a number be used in any one field, as in such cases the alfalfa might be badly trampled.

flies to feed upon and to the fact that the greater part of the fields was kept closely grazed, making the alfalfa less favorable for the laying and development of the eggs. Under such conditions the number of eggs deposited in a given field is greatly reduced. Many of the eggs laid on the young growth under such conditions are destroyed by the grazing of the stock, and the percentage that develops is kept at a minimum. Later on it was noted that on the stock ranches visited the disease previously mentioned, which is common to lepidopterous larvæ, was more prevalent in pastured ranches than in hay ranches. The prevalence of the disease in such fields is due to the fact that usually a few days after stock are turned in the alfalfa becomes trampled. The ground and the alfalfa are very moist, there being more or less dew every morning, and droppings from the cattle bring about a foul condition in the field, thus assisting in the retention of moisture, which, in turn, is conducive to the development of the disease.

If fields can be systematically and carefully pastured, damage from the caterpillar will accordingly be at a minimum. Cattle should never be allowed on a field when wet nor for too long a period, say from 24 to 35 days, and disking or renovating should always follow so as to loosen the soil and place it in a receptive condition for future irrigation.

It is on ranches and fields from which successive crops of hay are taken that the height of the damage is reached. In such fields the conditions for the development of the species are as nearly ideal as possible, and here the worms are ordinarily unmolested in their feeding and growth. The period elapsing from the time that one crop is cut until another is ready for harvesting so nearly coincides with the length of the period necessary for the development of any one generation of the butterfly that the cutting of the hay, as ordinarily carried on, does not reduce their numbers or disturb their work, since the worm will likely be in the advanced stage, or, perhaps, have passed into the pupal stage, before the crop is cut.

CONDITIONS AFFECTING INJURY.

As has been pointed out, this insect is ordinarily kept in control by its natural enemies, such as insect parasites and diseases, and it is only upon the occurrence of conditions unfavorable to the development of these enemies that serious outbreaks occur. It has also been noted time and again, both by the writer and others, that the seriousness of the damage quite often depends upon the farming methods used by the individual whose fields are attacked, or upon certain other conditions, such as character of soil, quantity of water for irrigation, location of land, etc. The former are conditions that the individual may remedy by changing his methods, while the latter may be practically alleviated by proper handling of the farm in question.

The damage in some alfalfa fields is quite often apparently correlated with the condition of the soil. A field seriously damaged often reveals a poor soil—at least a soil not well adapted to alfalfa culture, and consequently producing a slow-growing crop. Of course not all of the fields damaged were of poor soil; some of the very best alfalfa fields were seriously ravaged, but in these cases this was often attributable to other factors. Sandy loams or light soils are the best for alfalfa production, and consequently are the least damaged, owing to the fact that the alfalfa, growing more rapidly, is often able to recover from insect attacks and be ready for harvest before any noticeable damage has been done. A heavy soil can be improved and the growth of the alfalfa increased by deep plowing and thorough preparation of the seed bed at time of seeding the crop and then by renovating the alfalfa several times a year, either by disking or by the use of an alfalfa renovator. By such a procedure in irrigated regions the soil will more readily take water, and thus plant growth will be stimulated.

A farmer who attempts to use up-to-date and proper cultural methods is unfortunate indeed when his alfalfa fields, for which he is caring properly, are just across the fence from fields that are run down, and hence are breeders of insects. No matter how careful his efforts, some damage may be done owing to reinfestation of his fields from the butterflies supplied by his neighbor's field. Nevertheless enough may be accomplished through his own efforts to pay many times.

Again, the amount of water applied is often insufficient, sometimes because of neglect on the part of the rancher, and sometimes because of scarcity of supply. The former case is under the rancher's control; he should use care in applying the water and should eliminate waste. Sufficient water should be used to provide for the prompt development of the alfalfa crop, for in this way the farmer can reap his crop earlier and before the caterpillars have effected much damage.

Soon after agents of the Bureau of Entomology began observations and experiments looking toward the control of the species it was noticed that damage to alfalfa was often, although not always, associated with careless methods of farming and a lack of appreciation on the part of some ranchers of the benefits to be derived from careful, clean cultural methods. This is sometimes due to the fact that the rancher is trying to cultivate more land than it is possible for one man to farm successfully with the limited amount of labor and capital at his disposal. A great many times poor management is responsible for a failure where other methods would have meant success.

CLOSE CUTTING AND CLEAN CUTTING.

In harvesting the hay crop ranchers usually have to depend upon labor that, while often the best obtainable, is not by any means of the best class, and thus cutting is often done in a careless manner, stubble is left high and ragged, bunches of hay are left uncut at turning rows or on borders, ditch banks and fence rows are rarely or never cut, and the field presents the spectacle shown in Plate I, figure 3, page 4, and Plate II, figure 3. Thus any caterpillars that may still be present have a considerable amount of alfalfa upon which to feed and develop, and soon do so, so that the butterflies from these are ready for the next crop. Such places also afford bloom which attracts adult butterflies from other fields, and these lay eggs on the new alfalfa that soon springs up. If such neglected fields are treated as are those shown in Plate II, figures 1 and 2, there will be no food to enable any remaining caterpillars to complete their development; besides this, there will be no protection for them from an early irrigation or the rays of the hot sun, either one of which will kill them. Heat of the midday sun, accompanied by prompt irrigation immediately following such clean cutting, will nearly always kill Eurymus larvæ, especially in the warm Southwest. This is such an important item that one should not hesitate to go to the necessary expense in order to secure such a condition of cleanliness. In two cases in the Imperial Valley in 1910 it became necessary, because the hay had lodged badly, to remow a field at a cost of from 30 to 50 cents per acre, and in each case the results obtained in the following crop more than paid for the cost of the experiment.

EXPERIMENTS AND OBSERVATIONS IN CALIFORNIA.

In California, in 1910, 10 fields were selected in which good cultural conditions were to be created and in which methods were to be inaugurated that would not further the development of the caterpillars. The thing done in these fields was to put them under a system that would remedy as far as possible all or part of the defects recorded on a previous page. During that season (1910) a large part of the damage was due to the caterpillars of the third and fourth generations, the first and second not being numerous enough to assume any serious aspect. The task, then, was to keep their numbers below the point at which they could do any considerable damage. The time to start this control work was naturally with the earlier generations. The 10 fields mentioned (no two of which had had the same conditions of culture previous to that year, and which had all suffered more or less damage the year before, namely, in 1909) were given what might be termed clean culture, or careful management. Just as soon as possible after removing a crop of hay

FIG. 1.—FENCE ROW BORDERING ALFALFA FIELD, SHOWING CLEAN CUTTING, WHICH HELPS TO REDUCE THE ALFALFA CATERPILLAR AS WELL AS OTHER INSECT PESTS. (ORIGINAL.)

FIG. 2.—ALFALFA FIELD SHOWING CLOSE, CLEAN CUTTING NECESSARY FOR REDUCING A GENERATION OF ALFALFA CATERPILLARS. (ORIGINAL.)

FIG. 3.—FENCE ROW AND DITCH BANK SHOWING NEGLECTED GROWTH OF ALFALFA AND GRASS, WHICH OFFERS PROTECTION AND HIBERNATING QUARTERS FOR THE ALFALFA CATERPILLAR AND OTHER INSECT PESTS.

CLEAN CULTURE AND THE ALFALFA CATERPILLAR.

the field was irrigated thoroughly, thus starting the growth quickly. The field was again irrigated as soon as the dry condition of the crop required, and thus the growth was forced and not allowed to be checked.

It requires about 28 days to produce a hay crop in the Imperial Valley—a little longer than this in the spring and fall, and a few days less in warmer weather. It also takes practically the same period of time, as has been shown on a previous page, for the butterflies to develop from egg to adult. Now, if the crop of hay be forced by frequent watering, or because of good soil conditions, the worms will not have gone into the resting stage at time of cutting, but, instead, will still be feeding on the green alfalfa, and when the hay is cut and removed conditions will be unfavorable for their development and their food supply will be reduced. The hay in these fields was cut just as it was coming into bloom, which is a few days sooner than it is generally thought advisable to cut it. The advantage of this early cutting is often very important, for if worms are present in damaging numbers they will take a whole field in a short time. In this case not only will the hay be saved, but a major portion of the larvæ, if clean cultural methods are used, will find a lack of the food necessary for their complete development, and this, associated with hot weather and irrigation following the removal of the cured hay, will cause them ultimately to perish.

Of the 10 fields handled according to these methods only 1 was damaged to any considerable extent. The other 9 were not entirely free from larvæ, but the numbers were so reduced as to preclude any chance of noticeable injury to the alfalfa. In the one exceptional field the damage was due to the fact that irrigation had been delayed for nearly two weeks after the cutting of the second crop, owing to a new ditch which was under construction. Being a thrifty field naturally, the alfalfa had made a start, assisted by the moisture still present in the ground, and butterflies coming in from an outside field deposited eggs on this new growth, thus enabling the worms to destroy the best of the crop after it was finally irrigated. As a result almost an entire crop was lost. A field adjoining on the south, which had been irrigated immediately after cutting, was not in the least damaged. This was a lesson in itself, as it indicated the necessity for prompt work.

These observations in California in 1910 have been further supplemented by observations at Tempe, Ariz., and El Centro, Cal., in 1912. This year (1912) the writer made two trips into the Imperial Valley. Several ranchers had kept records of their methods of handling alfalfa, and these records show conclusively the same results as those of 1910. Two ranchers especially were found who had prac-

tically controlled the pest in the last few years, and they have accomplished it altogether by such methods as have just been described. One of these men, Mr. Henry Stroven, whose ranch is north of Holtville, says that he has had a minimum of damage. His ranch evidences his careful and systematic cultural methods. Ditch banks and fence rows are clean, and there is scarcely a weed noticeable on the entire ranch. Mr. Stroven informed the writer that he always renovates twice a year and sometimes oftener and also aims to keep his alfalfa abundantly watered in order to get a quick, thrifty growth. The other rancher, Mr. William Mansfield, of Brawley, practices the same methods in use by Mr. Stroven, and his ranch also shows this. Neither of these ranchers aims to allow his alfalfa to stand longer than five years in a certain field. Instead, he plows it up, raises some other crop for a year, and then reseeds to alfalfa, thus bringing into play a system of crop rotation which not only keeps the soil in excellent condition, but prevents insect increase. Mr. Mansfield told the writer that in 1908 he had considerable damage when his May cutting was getting a little more than two-thirds grown. One day he noticed that damage from the caterpillar was very apparent. The next day the effect was much more noticeable. So he mowed the alfalfa, taking it up at once, and irrigating as soon as possible. He thus saved by far the greater part of the crop infested and, besides, was not troubled again that year.

The following observations, made by Mr. R. N. Wilson in July, 1913, also bear out the foregoing statements:

> One farm was examined near Meloland, Cal., to-day. This is a dairy farm belonging to Mr. Cook. In order that the hay may be in the best condition, Mr. Cook cuts it just as it comes into bloom. He in this way gets two more cuttings of hay per year than his neighbors, who allow their fields to come to full bloom before cutting. His crops have never been badly injured by Eurymus, while his neighbors have more or less injury every year. He also keeps his alfalfa in a thrifty condition, and the rapid growth is another element in Eurymus control.

These three examples show the practicability and the success of the methods proven by observation and experimentation to be means of controlling outbreaks of the alfalfa caterpillar.

EXPERIMENTS AND OBSERVATIONS IN ARIZONA.

Observations similar to those in California were made in Arizona by the author in 1912 and in 1913 by Mr. T. Scott Wilson. The same relation has been noted to exist between clean culture and good farming methods in general and damage by the alfalfa caterpillar as existed in California. But in Arizona, as the soil conditions are somewhat different from those in California, it is necessary for the application of water to be even more timely. In many parts of the

Salt River Valley there is a layer of subsurface water. This is lacking in the Imperial Valley. Thus when a crop has been removed in the former place alfalfa soon sprouts, and eggs are laid sooner and have made some headway when irrigation has finally been accomplished. While there is a limit to the promptness with which a crop can be removed from the ground after being cut, and consequently a limit to the promptness with which the ground can be irrigated, yet these measures should always be carried out just as soon as possible, thus avoiding damage by reason of the difference noted.

In 1912 Mr. Peter Aepli, living a mile south of Tempe, began cultural methods especially meant to control outbreaks of the alfalfa caterpillar. It is to be noted that even previous to this time Mr. Aepli had carried on a system of crop culture that would secure the maximum returns from his land; so that about the only change in his methods was an addition of factors that take into consideration the status of the alfalfa caterpillar at the time of each cutting; that is to say, he cuts at a time that will do the most harm to any larvæ that may be present and before any damage is done to the alfalfa. August 1, 1912, it was found that a considerable number of caterpillars were present in Mr. Aepli's field and that he would have to cut earlier than he had intended in order to save it from serious damage. On August 3 he cut the hay, doing a fine clean job. On August 5 he removed the hay from the ground and then followed this with disking and irrigation. The worms were all killed, the present crop saved, and no further damage was done to the alfalfa in that field that year. The effect of these careful and painstaking methods was also noted in the field the year following. From Mr. T. Scott Wilson's notes of August 4, 1913, is quoted the following:

> An 80-acre field of alfalfa across the fence from Mr. Aepli's is almost completely destroyed, while Mr. Aepli's is damaged but very little. Mr. Aepli is cutting his hay to-day. The larvæ are not full grown yet, so he is taking their food from them before they mature. He usually cuts his hay close to the ground and before it gets too ripe, hence Eurymus do not bother him much.

Another example of the effect a careful system of clean cultural methods will have upon caterpillar devastations is noted in a 640-acre ranch just south of Tempe, Ariz. Here the clean-up methods are accomplished by a combined system of haying and pasturing and are quite successful. The ranch should really be termed a cattle ranch, but after the owners' young steers that have been raised on their range in northern Arizona are fed out in the winter and spring, several crops of hay are made, stacked up in the field, and fed the next winter. The hay from such crops is cut often, not allowed to get overmatured, and as the owners employ a large force of men it is hastily stacked and then, following this, 40 to 60 head of steers are turned in for about three days, during which time they clean up

every growing sprig in the field. They are then sent to another field, and so on and on, the owners in this way keeping their alfalfa ahead of the butterflies, and by the clean-up method few larvæ are allowed to develop to adults. Of course, not everyone can have stock available at just the right time, but this is another example of what clean-up methods will do.

IRRIGATION AS A FACTOR IN CONTROL.

As has been stated in a previous paragraph, moisture is conducive to the development of the disease which plays an important part in the control of this insect. A number of experiments were therefore tried by which, with the use of irrigation water, an attempt was made to supply moisture artificially so that the worms would become diseased. This was found to be quite successful. In fields where clean methods of cutting are used at haying time and this is immediately followed by irrigation, there seems little doubt that a part of the mortality of the larvæ is due to the effect of irrigation. The beating sun, of course, kills a great many, and then, as has been shown, under such a procedure the food supply is cut off and the decayed remains of larvæ are found hanging in great numbers to the alfalfa stubs about two days after such a procedure. This led the way for other experiments; accordingly, during the summer of 1913, Mr. T. Scott Wilson made a number of observations on irrigation of alfalfa at a time when the worms were beginning to appear numerously, and he found that invariably this gave the disease the necessary moisture and the worms soon died. For a rancher to take advantage of this would, of course, mean that he must have water available any time he wants it, which is not the case in all irrigated regions, as water is usually distributed in turn. However, in cases where the time for irrigation corresponds with the occurrence of an outbreak the water can be utilized and the worms killed.

VALUE OF DISKING AND RENOVATION.

It has been suggested before that an alfalfa field should be disked or renovated annually, or oftener, in order to keep the sod in good loose condition, so that it will take water readily and be aerated, and also to kill weeds. If teams are available, the best procedure would be to renovate several times, or at least twice a year. The usual method is to renovate once, and this during the winter. Now, if the alfalfa can be renovated in August, immediately after the third crop is removed, not only will the ground be placed in an excellent condition and weeds killed, but any larvæ or pupæ on the ground will be killed and future crops protected from damage. Some ranchers do this already and claim great results for it, and

a few even renovate oftener. Mr. Stroven, of Holtville, Cal., renovates just as often as it is possible for him to do so, and in 1911 this was four times. Leaving the matter of insects entirely out of consideration, enough benefit is derived from renovation to pay many times for the cost of the work. If a disk harrow is used, it should not be set at an angle, as this would be likely to cause injury to the crowns, but should be run straight and forced into the ground by weights.

DIRECT METHODS OF CONTROL.

INSECTICIDES.

In dealing with insect pests affecting cereal and forage crops it has proved possible in only a few instances to control them by the use of any of the various insecticides or poisons. The reason for this lack of success lies largely in the fact that such crops are distributed over a wide area, and the expense of application of any insecticide as a control measure is necessarily high, while a lack of thoroughness is likely to arise when one tries to keep the expense of treatment down to an economical basis.

Since the alfalfa hay is fed to stock, it is not possible to use any of the arsenical poisons against the caterpillar of the alfalfa butterfly. A few experiments, however, were tried with pyrethrum, or "buhach." As this is not a poison, and since its fatal effect upon the larvæ of butterflies is produced externally through their breathing pores, there would be no danger to stock. Pyrethrum was used in one case in 1910 in full strength, and in another instance it was diluted with equal proportions of flour. An application was made by dusting this substance from a cheesecloth sack, following the primitive method of applying Paris green to potato vines, at the rate of 3 pounds of pyrethrum to the half acre, which in the case of diluted material would make 1½ pounds of pyrethrum to the half acre. This first test was made on July 8, 1910, and no results were obtained, because of the fact that just two days later practically all of the worms in the field where the test was being made were destroyed by the malady before mentioned. The same experiment was repeated, however, on September 22, and in this case the results were negative, not a caterpillar being killed. It would seem, therefore, that the application was not sufficiently heavy to kill the worms, and that to have increased the amount of pyrethrum applied might have resulted in the eradication of the pest; but as the cost of pyrethrum at the rate of 3 pounds to the acre is already nearly $2, without considering the expense of application by hand, this could not be considered from an economic point of view.

In 1913 some additional experiments were tried with the same material by Mr. T. Scott Wilson at Tempe, by using it full strength. This killed about 50 per cent of the larvæ, but the cost of application

was again too high, and a large enough number of worms were not killed to justify the expense incurred.

ROLLING AND BRUSH DRAGGING.

At the time a field is being damaged by the worms the hay that remains undestroyed can be cut and then either a brush drag or a roller run over the ground, by which a great many of the larvæ will be destroyed. Some experiments tried along this line by Mr. T. Scott Wilson were quite successful. On August 15, in a 5-acre patch a brush drag was used and a great many larvæ were killed. This field was overrun by Bermuda grass, which protected many larvæ that would have been killed. A roller here would doubtless have

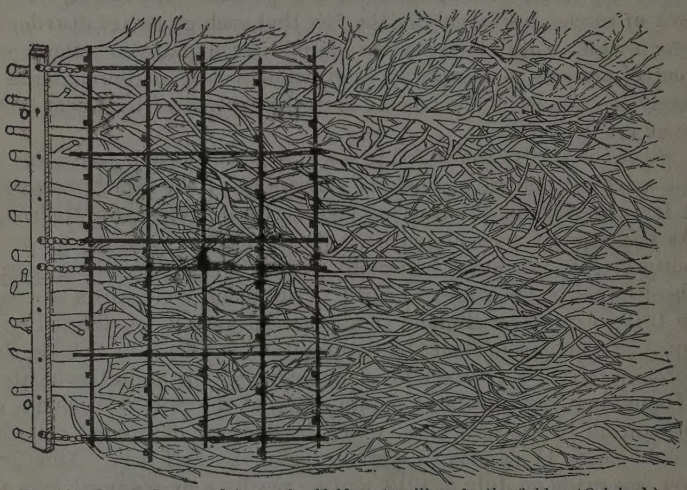

FIG. 20.—Brush drag used to crush alfalfa caterpillars in the fields. (Original.)

mashed all larvæ. On the 26th of August another test was made, using the same drag. In this case the larvæ were about full grown, and 55 per cent were killed by the operation. The latter experiment, however, was carried on in alfalfa of considerable height, and consequently the larvæ were afforded much protection and as large a percentage was not killed as would have been the case had the dragging immediately followed cutting.

A good brush drag and one that is well adapted to dragging alfalfa is shown in figure 20. The plan for constructing this, as given by Mr. E. S. G. Titus, in Bulletin No. 110 of the Utah Agricultural Experiment Station, is as follows:

The drag is made by laying the butts of rather short brush, five or six feet long, in a row on a plank twelve or fourteen feet long, then another row should

be laid upon the first, consisting of longer brush, with the butts trimmed a little further back so that you will have in effect two brush harrows, one following the other. Another plank should then be laid on the brush butts and bolted to the under plank. In weighting this drag, lay an ordinary tooth harrow, with the teeth down, directly on the brush drag. This makes a very even weight, at the same time it is so flexible that the drag will work its way down into the small depressions as well as over the larger elevations of the fields.

A larva exposed to dust and hot sun soon dies. On September 4 three larvæ were placed in a dusty spot by Mr. Wilson, and within a few minutes all were dead. The next day the experiment was repeated, and all larvæ died. In all about 50 larvæ were exposed to the dust and sun, and of this number only 1 was able to crawl back to alfalfa, the rest dying before they had crawled 10 inches on the dust and dry dirt. The sun was very hot, and the temperature, 4 feet from the ground, was 97° F. These experiments show why so many larvæ die following careful methods of haying. They have no protection from the hot sun when such methods are carried on.

CONCLUSIONS REGARDING CONTROL.

Keep the ranch in the best possible cultural condition. Irrigate it often and thoroughly and as soon after cutting as the crop of hay can be removed from the ground.

Renovate every winter and during the month of August, or even oftener if possible, either by disking or by the use of an alfalfa renovator, thus disturbing any pupæ that may be present, and putting the land and alfalfa in condition for good growth of succeeding crops.

Cut the alfalfa close to the ground and clean, especially along the ditch banks, borders, and turning rows, as well as in the main part of the field.

Cut the alfalfa earlier than is the general rule. The proper time is when it is just coming in bloom or is one-tenth in bloom. Watch for caterpillars in the early spring crop, and if many are observed about grown, cut the hay a few days before it is in bloom, and thus save the next and future crops.

A minimum amount of damage occurs in fields that are systematically pastured all or a part of the time.

A field should never be abandoned because the caterpillars threaten the destruction of a crop of alfalfa before the hay can possibly mature. Mow it at once, cutting it low and clean, thus saving part of the present crop, and in so doing starve, and allow the heat of the sun to kill, a great many of this generation of worms. Follow this by disking and then by either rolling or brush dragging, and a great majority of any remaining larvæ will be killed. The ground

should then be thoroughly irrigated, and by these efforts the coming crop will be assured.

Turkeys and chickens when allowed the run of a field will keep the numbers of the caterpillars at a minimum.

The protection of toads should be encouraged, as they eat many of these insects, as well as other injurious forms.

It has been noted that a carrying out of only part of these recommendations will not at all times save one's crop. The best results come to the one who is thorough in methods.

Cooperation among all farmers is necessary to suppress an insect attack completely. An occasional outbreak has been known to occur upon a farm or ranch that is under the best possible condition of crop culture, but in each case it was noted that the careless methods of a neighbor were responsible for the reinfestation.

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